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TOWARDS A CONCEPTUAL REMODELING OF INFORMATION TECHNOLOGIES BASED ON A BROAD CONSIDERATION OF COMPLEXITY

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Abstract: One strategy for managing the complexity of the world is to introduce a conceptual complexity device in the very center of the study, development and application of the specific techniques used to cope with the world.

This paper describes the guidelines of a research program for developing an integrated way of tackling the specific field of information technologies (I.T.s) --giving greater emphasis to informatics-- by means of a complexity approach. At the initial stage, concepts on complexity based on the metaphor system are a great help.

Bearing in mind the author's occupation, it is his hope that the results of this program will initially be a useful teaching tool for high-level I.T. professionals or future professionals. For this reason, greater effort will go into probing the model representing the complexity of I.T.s.

The embryo of this program has been used for the last two years at the Escuela Técnica Superior de Telecomunicación in Madrid.

1. INTRODUCTION

It is a fact that general systems have had little success in the field of education. Boulding mentioned this not too long ago when pointing out how professors of general systems courses usually manage to teach this subject "under an assumed name" (1). In our case, virtually the contrary has occurred.

Since 1978, the author has succeeded in including in the curriculum of Madrid's Escuela Técnica Superior de Ingenieros de Telecomunicación semester courses entitled Cybernetics and Systems Theory 1 and Cybernetics and Systems Theory 2, which later became Cybernetics and Systems Theory and Systems Engineering. After seven years of teaching the first course, the contents of which centered on Klir's classical text (2) and a favorable, albeit somewhat cold, reception, during the 1985-1986 school year the decision was made to change the contents of the course completely, while leaving the name of the course intact.

The course's new approach centers on the study of information technologies and their impact based on complexity. It must be said that this approach was welcomed by students and initially represented for the author an unsuspected way to introduce the basic concepts of general systems and a feeling for systems, in particular: in other words, this approach motivates students towards interdisciplinarity and a sociotechnical viewpoint. (A paper on the educational aspects of this experience is being prepared for another congress.)

2. NEED FOR AND SCOPE OF AN ARCHITECTURAL SCHEME FOR THE COMPLEXITY OF INFORMATION TECHNOLOGIES

In the constant changes in the world, in general, and in information technologies (I.T.s), in particular, complexity is ever-present in various shapes and forms.

This is our point of departure: the inevitable and growing presence of complexity as something verifiable. This idea must be immediately completed with two other no less important ideas: a) complexity has negative and positive aspects; b) complexity depends, in part, on the observer and on the devices available to the observer to carry out his work.

By initially accepting as broad a concept for complexity as that presented in Table 1, it is our intention to design and follow an eclectic program for seekiing out and adapting the various constructs with which an architectural scheme can be drawn for complexity in a very specific field, the field of

I.T.s (and more specifically, informatics). Complexity is undeniably a new dimension of I.T.s, though up to the present it has not been systematically studied except in one of its branches (computational complexity). For this reason, we lack an organized body of knowledge for our purposes.

COMPLEXITY IS THE NAME WE ARE GIVING TO THE CONDITION OF HUMAN BEINGS, OBJECTS, PHENOMENA, PROCESSES, CONCEPTS AND FEELINGS BECAUSE:

A) THEY ARE DIFFICULT TO UNDERSTAND OR EXPLAIN;
B) THEIR CAUSES, EFFECTS OR STRUCTURE ARE UNKNOWN;
C) THEY REQUIRE EITHER A GREAT DEAL OF INFORMATION, TIME OR ENERGY TO BE DESCRIBED OR MANAGED OR A HUGE, COORDINATED EFFORT ON THE PART OF PERSONS, EQUIPMENT AND MACHINERY;
D) THEY ARE SUBJECT TO A VARIETY OF PERCEPTIONS, INTERPRETATIONS, REACTIONS AND APPLICATIONS THAT ARE OFTEN CONTRADICTORY OR DISCONCERTING;
E) THEY PRODUCE EFFECTS THAT ARE SIMULTANEOUSLY DESIRABLE AND UNDESIRABLE (OR DIFFICULT TO CONTROL);
F) THEIR BEHAVIOR, DEPENDING ON THE CASE, MAY BE UNPREDICTABLE, RELATIVELY UNPREDICTABLE, EXTREMELY VARIABLE OR COUNTERINTUITIVE.

TABLE 1

Table 2, which presents a general program for research areas, has one significant limitation, that of restricting itself to artificial systems. We assume that this table includes such items noted above as point of departure and those in Table 1.

IN ARTIFICIAL SYSTEMS, WHAT DOES COMPLEXITY CONSIST OF?

A) WHAT FACTORS DOES IT DEPEND ON?
B) WHAT SHAPES DOES IT TAKE?
C) WHAT ARE ITS CONSEQUENCES?
D) HOW DOES IT EVOLVE?
E) WHAT CAN BE DONE TO PREPARE FOR, MEASURE AND MANAGE IT?

TABLE 2

The last step involves making Table 2 more operative by tailoring it to the specific artificial systems of I.T.s and shaping it by means of a set of guidelines defined by the key words 'engineering,' 'system' (*) and 'human framework' (see Figure 1).

(*) We recognize the notion or metaphor of a 'system' as the simplest basic complex unit, but one which does not exhaust the possibilities of a complexity paradigm, according to Morin (3).

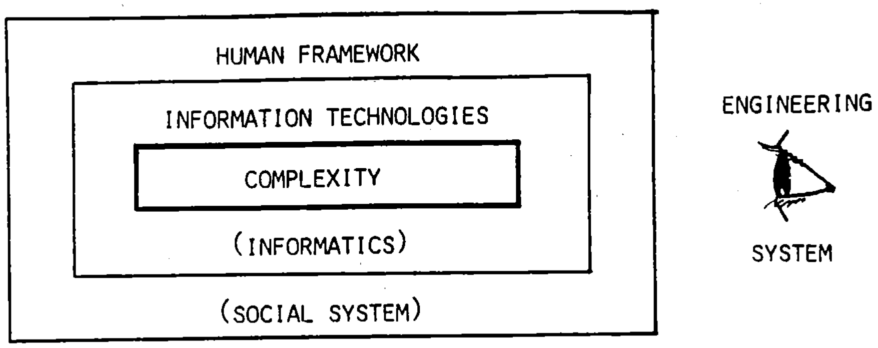
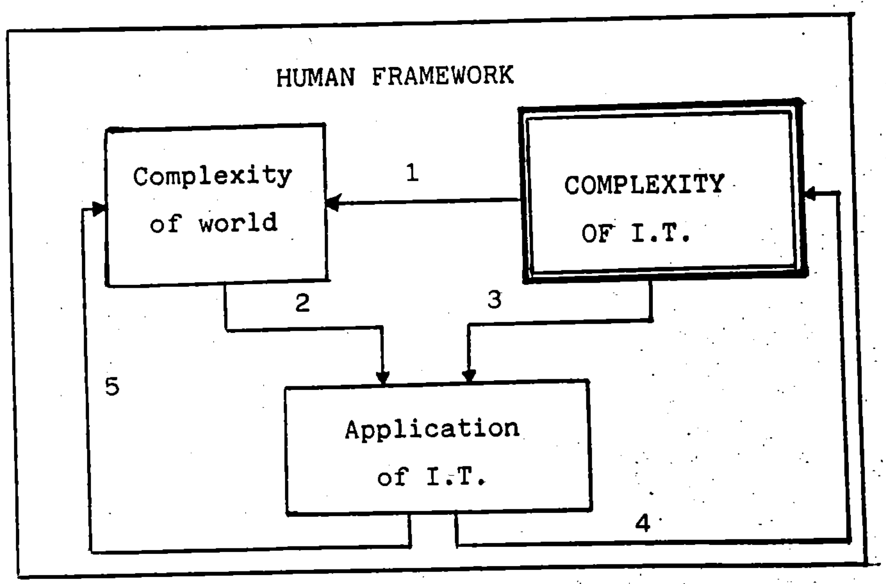


FIGURE 1

With our aim to design a technical-humanist architecture of complexity of I.T.s, we are in fact attempting to establish a small group of basic constancy traits for the workings of the world (in the area related to our specialized field).

3. INTERRELATIONSHIPS BETWEEN THE COMPLEXITY OF THE WORLD AND THE COMPLEXITY OF I.T.s. A WORKING DIAGRAM

If we wish to consider the complexity of I.T.s within the human framework, we must necessarily consider the observer in the broadest sense possible. In other words, we must view the complexity of the world as the complexity of the social system. Figure 2 presents this viewpoint by developing various aspects of Figure 1 in a more dynamic graphic format. The more darkly outlined square reflects the intention to emphasize, for circumstantial reasons, the more technical and instrumental sides of complexity.



The arrows indicate the overall relationships and interactions which should guide the choice and organization of topics in the program.

Arrow 1. Beyond any question of a doubt, technological advances substantially contribute to the higher levels of complexity in the world. Its impact on our ability to manage time, space and information is multiplying. The tendency of I.T.s to move towards mutual integration through the highly active electronification, digitalization and computerization process underway could give rise to exponential changes in this impact (4), (5), (6).

Arrow 2. What does the complexity of the world consist of? In particular, what does the complexity of the world's institutions consist of, based on the lines drawn in Table 2, if we accept that the institutions have been modeled as artificial systems in accordance with Simon (7)? Effects such as the instability and systemic design pattern of institutions, present in such authors as Beer (8),(9) and Ackoff (10) and others, provide us with suitable study guidelines. Also helpful along these same lines are the opinions of social critics inspired by non-technological and, at times, antitechnological feelings, such as Illich (11), to give one example.

Arrow 3. What does the complexity of I.T.s consist of?

Arrow 4. Our diagram clearly situates complexity in a new dimension, non-trivial knowledge of which becomes a prerequisite for applying technology to the world (arrow 5). Moreover, it should be a prerequisite for designing or redesigning technologies themselves; in other words, it should propel itself as a conceptual base of knowhow and techniques for constructing, understanding and masking the inevitable heightened complexity of information technologies and their effects. One highly intense field of application in this regard is the design of "natural" human-machine interfaces. So-called next-generation computers, theoretically to be available in the 1990s, point in the same direction: they will combine maximum performance with conviviality (that is, the ability "to perform more humanlike intellectual functions like inference, association and learning, as well as nonnumeric processing of speech, text, graphics and patterns" (12)).

Arrow 5. Lastly, the positive aspect is the potential of I.T.s to help cope with the complexity of the world which, in the practical terms, prompts us to undertake an applied study (typical of engineering) of problems and techniques, so as to turn this potentiality into a reality in specific fields, e.g., office information systems in human organizations (13).

4. AN ATTEMPT TO SYNTHESIZE: EXPLORATION, CLASSIFICATION, DEVELOPMENT, APPLICATION. EXAMPLES

The foregoing has been a description of the main ideas outlining the work initiated towards a conceptual remodeling of information technologies based on a broad consideration of complexity. Basically, the task involves a study, reflection and synthesis aimed at identifying, defining and describing the various meaningful types of complexity, characterized by their properties, causes and scope, and at describing the respective devices, always in connection with the human factor and its various interactions with I.T.s, which can be used to handle these different types of complexity.

The author has already made some headway in this work, both through his classes and publications, the latter being a recently published book (14). From this work, for illustrative purposes the following schematic examples (which appear in no particular order and are by no means exhaustive) have been taken.

	PRODUCERS				USERS		DEVICES FOR MANAGING COMPLEXITY							
TYPES OF COMPLEXITY	DEFINITION	DESIGN	CONSTRUCTION	DESCRIPTION	EXECUTION	RELATIONSHIP	LANGUAGES	HIERARCHIES	MODULATION STRUCTURING	AUTOMATION	REDEFINITION	INTERFACES	"DIVIDE AND CONQUER"	PARALLELISM
SYSTEM COMPLEXITY		⟷	⟷	⟷			X	X	X	X	X			
PROGRAM COMPLEXITY			⟷	⟷			X	X	X					
COMPUTATIONAL COMPLEXITY					⟷								X	X
EPISTEMOLOGICAL COMPLEXITY	⟷	⟷	⟷	⟷			X	X	X		X	X	X	
PROCESSUAL ORGANIZATIONAL COMPLEXITY	⟷	⟷	⟷	⟷			X	X	X	X	X	X	X	X
RELATIONAL COMPLEXITY IN GENERAL						⟷	X			X		X		
COMPLEX THINKING						⟷		Training and sociotechnical Design						

TABLE 3

4.1. Classification and definition of some of the types of complexity and diverse techniques for managing complexity (see Table 3, in which the human activities affected are represented by a double arrow. This table presents the types of complexity analyzed in detail in class).

. epistemological complexity:	the complexity present when passing from the object to the system (according to Ashby and Klir)
. processual organizational complexity:	the complexity of process coordination and control
. complex thinking:	the complexity created by the mismatching of the user's and and the artificial system's cognitive processes

4.2. Observers can be divided into two large groups: the first group is that of technicians, which we call producers/designers (15) and which, in turn, can be subdivided into smaller groups, should the need arise; the second group is that of users, which can also be broken down into smaller groups. One category of observers that plays an important role in technological innovation processes is that of user managers and entrepreneurs, for example.

4.3. Software complexity can be studied by looking at four types of complexity. One good example of this line of reasoning is the SDI project:

system complexity
epistemological complexity
organization complexity
computational complexity

4.4. Three levels of complexity in informatics: the abovementioned types as well as other forms of complexity may be classified based on a broad three-level perspective (16):

Level 1: complexity of a component, e.g., program complexity;

Level 2: complexity of a system, e.g., complexity of an integrated circuit, of data base software or of a computer network;

Level 3: complexity of an anthropotechnical sys tem. Order, logic and disorder or conflict are all present at the same time. (This last aspect is a hard concept for a I.T. engineer to accept.).

5. CURRENT SITUATION

As was said earlier, our aim is to develop an intellectual device for complexity, ideologically based on a system-human observer binomial so that, through educational channels, it can be made available to engineers with a technical background in Information Technologies. For the time being, the author's teaching method, which successfully catches students' interest in complexity situations, involves the use of precarious tools comprising an outline of ideas and a disordered, open set of texts.

Plans have been made to conduct some additional studies with a view to amply justifying embarking on a systematic project for development the program described in sections 2, 3 and 4 of this paper. It is nevertheless difficult to secure economic support for this type of project in Spain.

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